SIMULATION OF TRAVEL PATTERNS FOR SMALL URBAN AREAS

by

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ABSTRACT

The objective of this study was to develop models which would simulate internal-external trips and external-external (through) trips. Regression analysis and cross-classification of data were tested in an attempt to predict the number of internal-external trips and the percentage of through trips. Regression analysis was used in the development of a through-trip distribution model. Grouping data for analysis created some problems; however, trial-and-error evaluation enabled selection of variables which produced reasonable results. Variables found to be most significant in the development of internal-external models were population and employment. For through-trip models, variables used were population, functional classification, AADT at the external station, and percent trucks. In developing through-trip distribution models, variables of significance were AADT at the destination station, percent trucks at destination station, percent through trips at destination station, and ratio of destination AADT to total AADT's at all stations (value squared).

Overall, the models developed in this study appear to be adequate for planning purposes when ease of application and accuracy of the models are considered.

Research Report
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offered for publication by the
Transportation Research Board

October 1978

INTRODUCTION

Agencies responsible for determining when and where to construct new urban highways and streets, or to improve existing ones, must consider many factors in the decision-making process. One such factor is the travel desires and volume of traffic which can be expected to use the facilities in the future. Estimates of future traffic patterns are made by various traffic simulation models, usually some mathematical expression with parameters and constants to simulate traffic flow. Alternative transportation systems can be evaluated in terms of costs and benefits by inputing socio-economic descriptors into a simulation model in order to determine traffic patterns and volumes. Travel patterns within an urban area are divided into three categories:

1. External-External or Through Trips -- trips originating and terminating outside the area.
2. Internal-External Trips -- trips originating inside the area and terminating outside the study area, or vice-versa.
3. Internal-Internal Trips -- trips originating and terminating within the area.

Historically, travel data for the three types of trips have been obtained from origin-destination surveys. The external origin-destination survey, in which drivers of vehicles are interviewed at the study area boundary, provides data for the internal-external and external-external trip types. Internal-internal trip data are generally obtained by home interview surveys, truck surveys, and taxi surveys. The collecting, coding, editing, processing, and summarizing of these data often represents a major portion of the time and cost of conducting a transporatation study. However, review of studies completed has indicated that there are many similarities in the models developed for trip generation and trip distribution involving internal-internal trips, making it possible to synthesize internal-internal trips by modeling. Many of the similarities involving internal-internal trips are also apparent in internal-external and external-external trips. Synthesis of the trips involves application of values from origin-destination studies to other urban areas having similar population and socio-economic characteristics. By emphasizing previously tested procedures and by selecting variables that characterize small urban areas in Kentucky, models were developed, herein, for simulating internal-external and external-external trips.

REVIEW OF LITERATURE

Differences between large urban areas and small urban areas are apparently significant enough to compel separation for modeling traffic. Most planners categorize those areas with less than 50,000 population as small urban areas.

Initial work in North Carolina was directed toward simulation of internal travel using trip generation data from either a small sample of home interviews or from data obtained from another similar urban area. By 1970, a procedure for synthesis of internal travel had been perfected to the extent that its use has become standard operating procedure *(1)*. In 1970 and 1971, Modlin, working with the North Carolina Department of Transportation, was successful in synthesizing internal, external, and through travel for small urban areas *(2)*.

For through trips, the estimating procedure consisted of three models *(3)*. The first dealt with estimating the percentage of through trips from each external station given the functional classification of the facility external to the cordon, the current AADT, the percentage of the facility external to the cordon, the percentage of panel and pickup trucks, and the urban area population. The second was a composite model composed of distribution models for each functional classification which produced a triangular through-trip table. A third model estimated the percentage of total external trips by vehicles garaged inside the cordon as a function of employment available within the urban area.

In another study *(4)*, previously developed corridor growth-factor models for developing future estimates of internal traffic in small urban areas were tested and modified. Regression equations were developed to provide data usually obtained from external cordon surveys. Alternative procedures for providing external survey information, based on historical data, were also developed. The completed procedure provided traffic volumes within the accuracy necessary for planning major throughfares in small urban areas.

Most studies of trip generation undertaken in the 1960's relied heavily on regression analyses. However, a recent study sponsored by the Federal Highway Administration indicated that a combination of cross-classification and rate analysis was a more efficient and straightforward procedure for forecasting trip generation *(5)*. Some advantages of using the combined cross-classification and rate analysis is the ease of understanding, efficient use of data, and ease of updating.

DEVELOPMENT OF MODELS

Transportation studies of 20 cities having populations ranging between 6,000 and 50,000 and scattered throughout Kentucky, were the primary source of data for the analyses.As is the case with most prediction models, the procedure followed was a trial-and-error process of selecting independent variables which were easy to predict, which met the test of reasonableness, and which produced statistically sound results. Model formulation was confined to regression analyses and cross-classification techniques.

INTERNAL-EXTERNAL MODEL

Inspection of internal-external equations developed in the urban area transportation studies reveals the types and the combinations of independent variables which were used to predict internal-external trips. The dependent variable (internal-external trips) and independent variables (various planning and socio-economic factors) were the best combination of variables to represent base-year conditions and to use to predict future trip generation. Internal-external trips were obtained from origin-destination surveys. Population and employment data were available from censuses, and projections of these variables were considered good predictors of conditions at some point in the future. The study areas were grouped according to population.

Regression Analysis -- Data on dwelling units, population, various types of employment, and internal-external trip attractions by zone were collected, tabulated, keypunched, and coded for computer analyses. Linear regression was the first type of analysis performed to derive a prediction model. Several combinations of independent variables were tested using data available from the 20 cities. Each internal zone was considered to be a separate set of data; therefore, a total of 816 sets of data were available. The data sets were reduced from 816 to 762 because some of the data sets exhibited unusually large, or small, internal-external trips. Regression analysis using the complete data was attempted. The result was a prediction equation which was inaccurate and unresponsive. A second regression analysis was made using the zones within each study area as a data set. These equations characterized individual areas well, but the equations were not applicable to predicting trips in other areas. It became apparent that the study areas should be combined into population groups. Regression analyses using five population groups were made, and the resultant equations are presented in Table 1.

Cross-Classification Analysis -- The second type of analysis used to obtain internal-external prediction models was cross-classification of data. Independent variables used for this analysis were zone population, total employment by zone, and dwellings by zone. The first cross-classification matrices were developed with large numbers of categories for each variable. It was found that the number of entries per cell was not sufficient to give significance to this high degree of stratification because only 816 zones constituted the data base. From regression analyses, it was found that dwellings and population exhibited characteristics of collinearity; and, therefore, one or the other had to be dropped from the regression equations. Since both variables relied on the same characteristics of the urban area for prediction purposes, dwellings were omitted from the cross-classification analysis. The resulting model in its final form is presented in Table 2. Total employment by zone and population by zone are stratified into five and three groups, respectively. Due to the unusual attractors (businesses and institutions) previously mentioned, only 762 of the 816 internal zones were used for the final cross-classification analysis. The number of entries per cell in the matrix is also shown in Table 2. The report on trip-generation analysis by the Federal Highway Administration *(5)* suggested that at least 25 observations be accumulated for each cell. Only two of the 15 cells had less than 25 observations.

EXTERNAL-EXTERNAL MODEL

Regression Analysis: Percentage Through Trips -- Using a North Carolina study *(3)* as a guide, a model was tested with several independent variables to evaluate the percentage of through trips in the AADT at external stations. Independent variables in the regression analysis were AADT at the external station, percent trucks, population, functional classification of the highway at the external station, and employment. The same areas used to develop models to predict the percentage of through trips were used in developing internal-external trip models. There were 20 urban areas and a total of 177 external stations.

Of the 177 external stations, four functional classifications were represented. There were 61 external stations on primary arterials, 102 on minor arterials, 11 on collectors, and three on local routes. In the North Carolina study *(3)*, functional classification was used as a dummy variable. The method of dummy variables involves coding the data in such a manner that only selected classifications would be entered into the regression equation; others would be omitted. Functional classification, however, yielded no improvement in the statistical values for the equation. Functional classifications were also considered in an equation for each class, but this also proved unsuccessful. Employment data did not significantly improve the predictive ability of the equation. Generally, it is best that prediction equations have relatively small constants; however, equations forced to have smaller constants were not acceptable because predictions were less accurate. After several attempts at segregating the data, the simplest equation which represented all functional classifications and gave the best predicting ability was developed as shown in Table 3.

Cross-Classification Analysis: Percentage Through Trips -- Recent work with cross-classification models has increased the confidence in this type of model for prediction purposes. Here, the first attempts to predict percentages of through trips using cross-classification were generally unsuccessful because too many variables and too much stratification were used. Population of the study area, functional classification of the route at the external station, AADT of the route at the external station, and percent trucks of the AADT were the variables first considered. Population of the area was dropped first because too many blanks appeared in the cross-classification matrix. Functional classification, which was not a significant variable when entered into the regression equation, was found to be a practical means of segregating data for cross-classification analysis. Cross-classification models were developed for primary arterial and minor arterial functional classifications; however, insufficient data were available to develop models for collector and local routes. The average percentage of through trips for the 11 collector routes and three local routes were used as representative of the 20 urban areas analyzed in this study.

After several attempts, the final cross-classification model used only three groups of AADT data and three groups of truck percentages for each AADT group. Therefore, for the models representating primary arterials and minor arterials, there were nine cells within each of the models. These models and the average percentage through trips representing collector and local routes are presented in Table 3, along with the regression equation model.

Regression Analysis: Distribution of External-External (Through) Trip Ends -- The distribution of external-external (through) trip ends was accomplished by developing regression equations for each of the four functional classifications such that trip ends were distributed from each functional classification to all other functional classifications. External-external trip data were available for only 17 of the 20 urban areas used in the development of the other models in this study. A total of 1,332 combinations of trip interchange data were available for use in the analyses.

External-external trip data had to be balanced and then doubled before being input into the distribution models. This was necessary to make the distribution of trips from one external station to all other stations equal to 100 percent. For example, if the balanced number of trips from external Station A to external Station B is 10 and the number from B to A is 10, then the total number of trips between the two external stations is 20. Handling the trip tables in this manner, the volumes at the external stations represent two-way traffic.

Of the 14 independent variables used in an attempt to predict the distribution of through trips, only four were considered significant enough to be included in the final model. To adequately represent two-way trips, it was felt that some function of both origin station and destination station be included in the model. However, results from the regression analysis indicated that variables representing the origin station were relatively insignificant; and, therefore, they were omitted from the equation. One variable, the ratio of the destination station AADT to the combined AADT at all external stations, did represent the origin station in an indirect way. The other three independent variables were AADT at the destination station, percent trucks at the destination station, and percentage through trips at the destination station. The models in their final form are presented in Table 4.

RESULTS

INTERNAL-EXTERNAL TRIP MODELS

Regression equations for internal-external trips are presented in Table 1. In the equations, internal-external trip attractions are a function of population of internal zone, commerical employment, public employment, and industrial employment by zone. Table 2 summarizes the internal-external cross-classification model. In this model, internal-external trip attractions are a function of employment by zone and population by zone. Figure 1 was prepared as a graphical representation of internal-external trip attractions as a function of employment and population by internal zone. For all three population ranges, the number of internal-external trip attractions increases with increasing total employment.

Several statistical values were used to evaluate the accuracy and reliability of the internal-external trip models. For the regression analyses, the statistical values were the squared correlation coefficient, standard error of estimate, mean of the dependent variable, and coefficient of variation. These values for each study and each group of studies are reported in Table 5. As should be expected, the statistical results for the individual study areas were better than the results for the combination of studies.

Table 6 presents data on the predictive abilities of internal-external regression models and internal-external cross-classification models for each of the study areas based on the group equations. Included in the table are the number of zones used, actual trips, predicted trips, and root-mean-square errors for each of the 20 study areas. Root-mean-square errors were used as a means of comparing the predicted values calculated from the regression equations and the actual data obtained from origin-destination surveys. Two-thirds of the time, the predicted values will deviate from the observed values by an amount no greater than the root-mean-square error.

It is obvious that considerably better predictions were achieved with the model developed from regression analysis as compared to the model developed by the cross-classification analysis. As shown in Table 6, the root-mean-square errors were significantly less for the regression model in all but one (Berea) of the 20 studies where combined equations were used to generate predictions. Results also indicated that greater accuracy was achieved with the regression model when the study areas were grouped by populaton. The large root-mean-square errors associated with some of the predictions can be explained in some cases because of the unusually large or unique producers and attractors of trips. As an example, the Murray area *(6)* was examined from the standpoint of eliminating unique zones to see how the error of prediction was affected. Three zones having employment three times greater than the average were discarded. The change in the root-mean-square error was from 346 to 249 for the regression model and from 693 to 238 for the cross-classification model. This indicated that the decision to discard some of the zones was very critical to the outcome of the prediction model. If some zones were discarded in the development of the general prediction model, then it would be necessary to estimate the internal-external trip attractions by some other means. The most valid estimates are based on data from past studies involving similar trip producers and attractors.

EXTERNAL-EXTERNAL TRIP MODELS: PERCENTAGE THROUGH TRIPS

As was shown previously in Table 3, the regression equation developed to predict the percentage of external-external trips was a function of AADT at the external station, percent trucks, and population. The statistical accuracy of this equation was reasonable; the standard error was 15.53, the multiple correlation coefficient (r^2) was 0.53, and the coefficient of variation was 49.

Table 3 gives the final cross-classification model used to predict the percentage of external-external trips at an external station. This model was also a function of AADT at the external station and percent trucks in the AADT at the external station, but the matrix did not include population. Functional classification was another means of segregating the data for the cross-classification analsyis.

Summarized in Table 7 is a comparison of the predictive abilities of external-external trip models. Included in the table are the number of external stations used, actual trips, predicted trips, and the root-mean-square errors for each of the 20 urban areas. The accuracy of the two models was approximately equal. However, the number of entries per cell in the cross-classification matrix was so small that the reliability of the results must be questioned.

EXTERNAL-EXTERNAL TRIP DISTRIBUTION MODELS

As a result of exhaustive regression analyses, equations for each of the four functional classifications were developed as was shown in Table 4. Each of the equations was a function of AADT at the destination station, percent trucks at the destination station, percentage through trips at the destination station, and the ratio of the AADT at the destination station to the combined AADT at all external stations.

Statistical results representing the accuracy of the models are presented in Table 8. While some statistical measures appear to produce inaccurate predictions, it is generally assumed that reasonably high standard errors exist with these prediction models. Results from these four distribution models compare favorably with results obtained by others *(2, 3)*. Overall, the models appear to be adequately reliable for planning purposes; this is true especially when the ease of application and the accuracy of the models are considered.

SUMMARY AND CONCLUSIONS

Three prediction models were developed: a model to predict the number of internal-external trips; a model to predict the percentage of external-external trips; and a model to distribute external-external trips. Both regression analysis and cross-classificaton techniques were tested in the development of the first two models, but only regression analysis was used to predict the distribution of through trips. Segregation of data into groups suitable for analysis did create some problems, but a method of trial-and-error evaluation enabled selection of the best combinationn of variables. Summarized in Table 9 are the independent variables required as input into the two internal-external models, the two external-external (through) models, and the through-trip distribution models. These independent variables were selected from data which were readily available, easy to forecast, and easy to monitor.

Population was the most significant variable which affected the outcome of the internal-external trip regression model. As previously noted, there were five population groups. These were found to be the most distinctive means of separating the study areas for analysis. Many of the small urban areas in Kentucky were found to have travel patterns very similar to other towns of comparable population. Although not verified here, other studies have shown that geographical distribution has considerable influence on travel patterns, as does the proximity of the town to interstate, parkway, or other major routes. Socio-economic characteristics of small urban areas also play a significant role in determining the travel patterns.

For predictions of internal-external trips, the regression equations presented in Table 1 should be used. These equations are categorized into five groups according to population of the urban area, and predictions of internal-external trips by zone are functions of zonal population and employment. The cross-classificaton prediction presented in Table 2 may have useful application if considerable care is taken to identify unique producers and attractors of trips and if special procedures for handling these trips are developed.

For predictions of percentage external-external (through) trips, the regression equation presented in Table 3 should be used. This regression equation is representative of all cases for predicting percentage external-external trips. The model for cross-classification is also presented in Table 3, but its utility is questionable because of the small number of entries in each cell in the matrix.

It was necessary to develop an external-external trip distribution model to implement results from development of a percent-through-trip model. Results from the percent-through-trip model can be input directly into one of the four distribution models presented in Table 4. This will enable the user to determine the percentage of through trips at a particular external station and then to distribute these trips to the other external stations within the study area. The final results will be an external-external triangular trip table.

Overall, the models developed in this study appear to be appropriate for planning purposes; this is true especially when the ease of application and accuracy of the models is considered.

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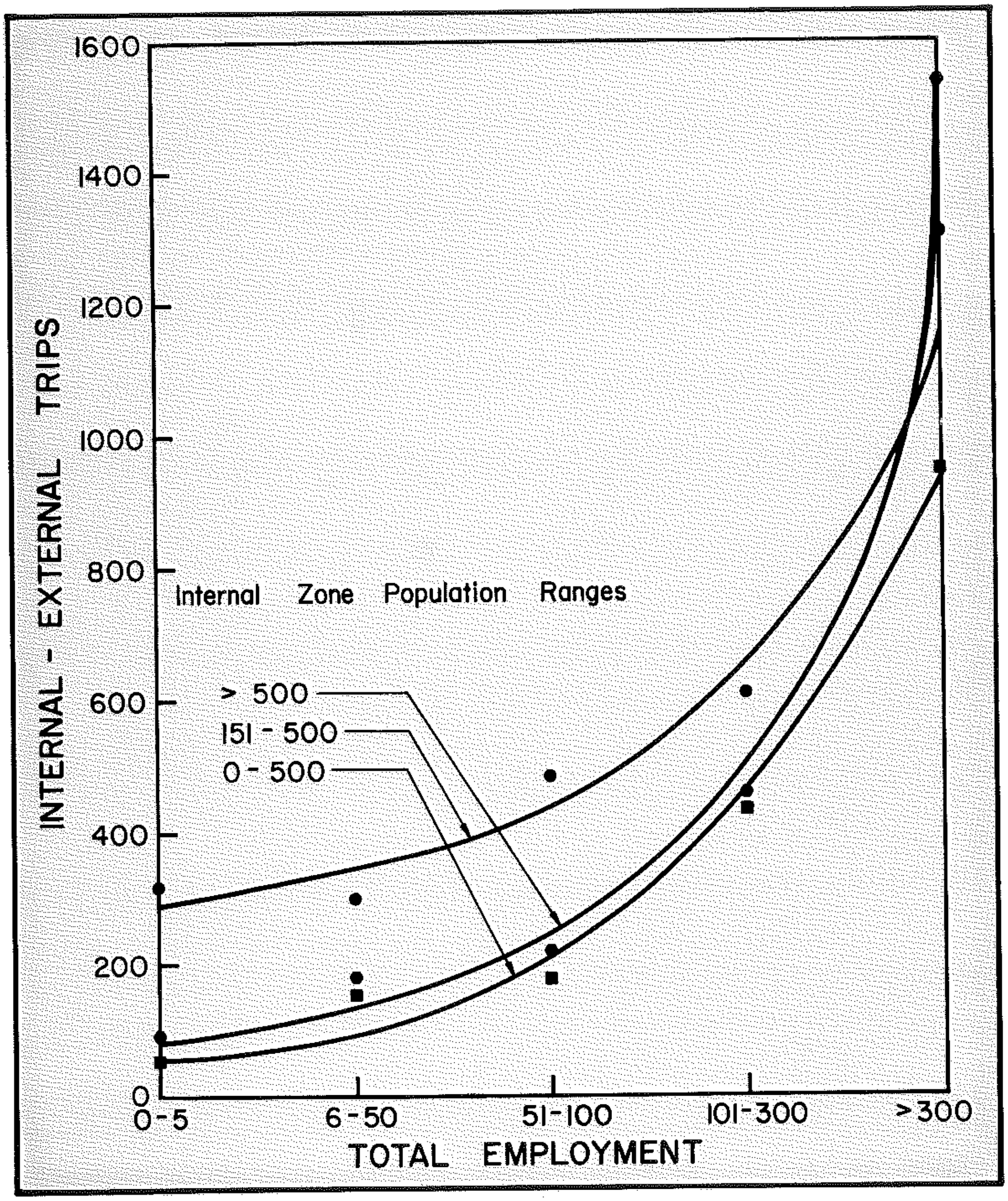

Figure 1. Relationship between Internal-External Trip Attractions and Total Employment for Various Population Ranges.

TABLE 1. INTERNAL-EXTERNAL TRIP PREDICTION MODELS (REGRESSION ANALYSIS)

NUMBER OF STUDY AREAS	POPULATION GROUP	EQUATION*
6	5,000 - 9,999	Y = 10.25 + 0.53 P + 5.41 C + 0.81 E + 0.57 I
7	10,000 - 14,999	Y = 123.45 + 0.15 P + 2.73 C + 3.20 E + 0.80 I
2	15,000 - 19,999	Y = -28.41 + 0.38 P + 2.72 C + 3.28 E + 0.69 I
3	20,000 - 29,999	Y = 1.78 + 0.30 P + 1.87 C + 1.64 E + 0.53 I
2	30,000 - 49,999	Y = 60.76 + 0.05 P + 1.26 C + 0.30 E + .051 I

*Y = INTERNAL-EXTERNAL TRIPS BY ZONE
P = POPULATION OF INTERNAL ZONE
C = COMMERICAL EMPLOYMENT BY ZONE
E = PUBLIC EMPLOYMENT BY ZONE
I = INDUSTRIAL EMPLOYMENT BY ZONE

TABLE 2. CROSS-CLASSIFICATION PREDICTION OF INTERNAL-EXTERNAL TRIPS PER INTERNAL ZONE

TOTAL EMPLOYMENT	POPULATION 0 - 150	POPULATION 151 - 500	POPULATION >500
0 - 5	59 (87)*	87 (51)	317 (8)
6 - 50	154 (46)	185 (73)	340 (63)
51 - 100	179 (22)	222 (39)	485 (52)
101 - 300	436 (30)	464 (70)	610 (87)
> 300	945 (42)	1,150 (43)	1,309 (49)

*( ) DATA ENTRIES PER CELL

TABLE 3. EXTERNAL-EXTERNAL TRIP MODELS

REGRESSION ANALYSIS

$$Y = 0.003\,A + 1.49\,T - 0.0007\,P + 17.43$$

WHERE Y = PERCENT THROUGH TRIPS OF AADT AT EXTERNAL STATION
A = AADT AT EXTERNAL STATION
T = PERCENT TRUCKS OF AADT AT EXTERNAL STATION
P = POPULATION OF URBAN AREA

CROSS-CLASSIFICATION

FUNCTIONAL CLASSIFICATION	AADT	PERCENT TRUCKS OF AADT	PERCENT THROUGH TRIPS	ENTRIES PER CELL
PRIMARY ARTERIAL	0 - 2,500	0 - 5	12	2
		6 - 10	31	3
		> 10	41	6
	2,501 - 5,000	0 - 5	39	2
		6 - 10	31	7
		> 10	49	15
	> 5,000	0 - 5	24	2
		6 - 10	49	10
		> 10	64	15
MINOR ARTERIAL	0 - 2,500	0 - 5	16	17
		6 - 10	20	30
		> 10	15	8
	2,501 - 5,000	0 - 5	28	9
		6 - 10	20	8
		> 10	36	18
	> 5,000	0 - 5	10	2
		6 - 10	32	4
		> 10	40	5
COLLECTOR	ALL	ALL	25	11
LOCAL	ALL	ALL	19	3

TABLE 4. EXTERNAL-EXTERNAL TRIP DISTRIBUTION MODELS

FUNCTIONAL CLASSIFICATION	EQUATION
PRIMARY ARTERIAL	Y = 0.0001 A + 0.11 T + 0.22 TT + 385.83 R - 2.58
MINOR ARTERIAL	Y = 0.0008 A - 0.08 T - 0.03 TT + 228.14 R + 6.20
COLLECTOR	Y = -0.00001 A + 0.11 T + 0.05 TT + 295.06 R + 3.10
LOCAL	Y = -0.01 A - 0.03 T + 0.83 TT + 2704.73 R + 1.95

WHERE Y = PERCENT OF TRIP ENDS FROM ORIGIN STATION DISTRIBUTED TO EACH OF THE OTHER FUNCTIONAL CLASSIFICATIONS
A = AADT AT DESTINATION STATION
T = PERCENT TRUCKS OF AADT AT DESTINATION STATION
TT = PERCENT THROUGH TRIPS OF AADT AT DESTINATION STATION
R = SQUARE OF RATIO OF DESTINATION AADT TO TOTAL AADT

TABLE 5. STATISTICAL COMPARISON FOR EACH STUDY AREA (INTERNAL-EXTERNAL REGRESSION EQUATIONS)

STUDY AREA	STUDY YEAR POPULATION	NUMBER OF INTERNAL-EXTERNAL ZONES	R	STANDARD ERROR	MEAN OF DEPENDENT VARIABLE	COEFFICIENT OF VARIATION
FRANKLIN	7,898	28	0.91	195	370	53
CYNTHIANA	6,700	20	0.98	138	563	25
HAZARD	6,145	15	0.97	243	906	27
MT. STERLING	7,695	19	0.90	293	771	38
NICHOLASVILLE	7,464	24	0.95	234	646	36
BEREA	9,210	24	0.81	120	331	36
COMBINED GROUP		130	0.81	353	564	63
MURRAY	14,713	20	0.95	240	970	25
GLASGOW	12,979	32	0.96	190	473	40
SOMERSET	14,031	20	0.87	383	1,188	32
ELIZABETHTOWN	12,300	45	0.94	195	488	40
DANVILLE	12,755	30	0.86	472	706	67
CORBIN	11,430	31	0.95	135	426	32
MAYFIELD	13,436	25	0.90	289	1,016	28
COMBINED GROUP		203	0.79	404	690	59
MADISONVILLE	18,224	48	0.96	147	411	36
WINCHESTER	16,205	30	0.95	179	627	29
COMBINED GROUP		78	0.94	171	494	35
HENDERSON	24,965	77	0.70	153	289	53
HOPKINSVILLE	26,647	74	0.84	93	224	42
RICHMOND	23,477	31	0.87	356	793	45
COMBINED GROUP		182	0.78	229	348	66
PADUCAH	50,000	95	0.58	133	212	63
BOWLING GREEN	36,553	74	0.79	153	309	50
COMBINED GROUP		169	0.71	143	255	56

TABLE 6. INTERNAL-EXTERNAL TRIP PREDICTIONS (COMPARISON OF REGRESSION ANALYSIS AND CROSS-CLASSIFICATION)

STUDY AREA	INTERNAL-EXTERNAL ZONES USED IN MODEL	ACTUAL INTERNAL-EXTERNAL AVERAGE TRIPS PER ZONE	CROSS-CLASSIFICATION PREDICTION (AVERAGE TRIPS PER ZONE)	CROSS-CLASSIFICATION ROOT-MEAN-SQUARE ERROR	REGRESSION PREDICTION (AVERAGE TRIPS PER ZONE)	REGRESSION ROOT-MEAN-SQUARE ERROR
FRANKLIN	28	370	311	459	418	203
CYNTHIANA	20	563	507	678	588	228
HAZARD	15	849	533	809	990	280
MT. STERLING	19	771	449	684	641	298
NICHAOLASVILLE	24	645	271	777	397	555
BEREA	24	331	369	274	532	316
COMBINED GROUP	130	564	488	621	563	339
MURRAY	20	970	652	693	910	347
GLASGOW	32	472	481	640	536	330
SOMERSET	20	1,187	704	882	900	459
ELIZABETHTOWN	45	488	395	554	534	254
DANVILLE	30	706	543	959	950	686
CORBIN	31	406	371	292	414	188
MAYFIELD	25	1,016	677	564	840	367
COMBINED GROUP	203	687	520	670	689	386
MADISONVILLE	48	411	476	626	445	156
WINCHESTER	30	627	533	551	580	186
COMBINED GROUP	78	494	498	598	498	168
HENDERSON	77	289	418	281	298	177
HOPKINSVILLE	74	224	421	437	298	147
RICHMOND	31	793	589	673	597	413
COMBINED GROUP	182	348	458	439	349	226
PADUCAH	95	213	450	329	212	136
BOWLING GREEN	74	309	585	435	285	171
COMBINED GROUP	169	255	509	380	244	153

TABLE 7. EXTERNAL-EXTERNAL TRIP PREDICTIONS (COMPARISON OF REGRESSION ANALYSIS AND CROSS-CLASSIFICATION)

STUDY AREA	NUMBER OF STATIONS	ACTUAL PERCENT THROUGH TRIPS AVERAGE PER STATION	CROSS-CLASSIFICATION PREDICTION (AVERAGE PERCENT TRIPS PER STATION)	CROSS-CLASSIFICATION ROOT MEAN-SQUARE ERROR	REGRESSION PREDICTION (AVERAGE PERCENT TRIPS PER STATION)	REGRESSION ROOT MEAN-SQUARE ERROR
FRANKLIN	6	25.3	23.5	8.5	33.3	11.6
CYNTHIANA	6	30.5	31.2	15.1	34.0	11.9
HAZARD	4	17.7	37.0	25.8	41.5	24.8
MT. STERLING	7	42.3	29.4	18.0	39.6	13.9
NICHOLASVILLE	7	41.8	34.4	12.7	36.0	9.9
BEREA	8	20.0	22.8	6.1	29.5	14.6
MURRAY	9	18.5	30.0	12.5	33.1	16.1
GLASGOW	8	33.5	36.1	15.1	35.4	14.0
SOMERSET	9	43.1	27.2	19.2	20.3	26.4
ELIZABETHTOWN	12	49.3	35.6	24.0	37.6	26.3
DANVILLE	8	28.1	34.9	11.5	31.6	7.7
CORBIN	7	44.1	42.1	15.3	31.6	28.0
MAYFIELD	12	31.7	30.2	17.4	30.3	15.7
MADISONVILLE	8	30.2	29.7	10.3	33.4	8.8
WINCHESTER	11	34.0	26.9	17.5	22.4	24.4
HENDERSON	10	47.2	34.9	19.4	27.4	25.8
HOPKINSVILLE	12	25.9	34.3	18.0	26.9	15.1
RICHMOND	7	28.0	30.8	13.4	23.1	8.7
PADUCAH	15	18.1	29.2	16.5	22.8	9.3
BOWLING GREEN	11	23.3	31.0	18.2	19.0	14.4
ALL AREAS	177	31.7	31.6	16.7	29.4	17.8

TABLE 8. STATISTICAL RESULTS FOR EXTERNAL-EXTERNAL TRIP DISTRIBUTION MODELS

FUNCTIONAL CLASSIFICATION	TOTAL OBSERVATIONS (FUNCTIONAL CLASS AT ORIGIN)	MEAN OF DEPENDENT VARIABLE	R^2	STANDARD ERROR	COEFFICIENT OF VARIATION
PRIMARY ARTERIAL	478	11.60	0.54	12.85	111
MINOR ARTERIAL	733	11.61	0.43	11.13	97
COLLECTOR	79	11.74	0.35	12.64	108
LOCAL	42	7.03	0.63	7.93	113

NOTE: REGRESSION EQUATIONS GIVEN IN TABLE 4

TABLE 9. INDEPENDENT INPUT VARIABLES

INTERNAL-EXTERNAL TRIP MODELS

REGRESSION EQUATION
1. POPULATION OF INTERNAL ZONE
2. COMMERICAL EMPLOYMENT BY ZONE
3. PUBLIC EMPLOYMENT BY ZONE
4. INDUSTRIAL EMPLOYMENT BY ZONE

CROSS-CLASSIFICATION
1. POPULATION OF INTERNAL ZONE
2. TOTAL EMPLOYMENT BY ZONE

EXTERNAL-EXTERNAL TRIP MODELS

PERCENTAGE THROUGH TRIPS

REGRESSION EQUATION
1. AADT AT EXTERNAL STATION
2. PERCENT TRUCKS OF AADT AT EXTERNAL STATION
3. POPULATION OF URBAN AREA

CROSS-CLASSIFICATION
1. FUNCTIONAL CLASSIFICATION AT EXTERNAL STATION
2. AADT AT EXTERNAL STATION
3. PERCENT TRUCKS OF AADT AT EXTERNAL STATION

DISTRIBUTION OF EXTERNAL-EXTERNAL TRIPS

REGRESSION EQUATION
1. AADT AT DESTINATION STATION
2. PERCENT TRUCKS OF AADT AT DESTINATION STATION
3. PERCENT THROUGH TRIPS OF AADT AT DESTINATION STATION
4. SQUARE OF RATIO OF DESTINATION STATION AADT TO COMBINED AADT AT ALL EXTERNAL STATIONS